would have partially supported research. Walker and Given reasoned instead that, if they gave Fessenden generous financial backing, he could develop a system of radio communications so superior to all rivals that the patents could be sold at a handsome price. They overrated the commercial potentialities of Fessenden's inventions, failing to recognize that there were many alternative methods of perfecting radio communications. They also made the common mistake of underestimating the time required to develop a new industry to the point of mass production. No one was willing to pay large sums for patents as long as the manufacture of radio apparatus remained primarily a specialized engineering job in which very few standard units were produced. It was not until after the first World War that the Fessenden system could be sold for a price at all commensurate with research and developmental expenses incurred.

The experiences of Walker, Given and Fessenden illustrate the difficulties inherent in launching a scientific enterprise when the men who put up the money do not understand the technical problems with which the company is dealing and when, as is so frequently the case, the key inventor has a troublesome personality.

2. Lee de Forest

(a) THE INVENTOR

Lee de Forest, the most prominent American inventor of the pre-war period, is primarily distinguished for the three-element vacuum tube or triode. Dr. Rabi, who recently won the Nobel Prize in physics, has described the three-element vacuum tube as "so outstanding in its consequences that it almost ranks with the greatest inventions of all time." [26]

The Triode

Lee de Forest was one of the first Americans to write a Ph.D. thesis on wireless telegraphy.[27] On graduation in 1899 he got a

[26] I. I. Rabi, "The Physicist Returns from the War," *Atlantic Monthly*, Oct. 1945, p. 109.

[27] "The Reflection of Short Hertzian Waves from the Ends of Parallel Wires," Yale University, 1899. Georgette Carneal, *A Conqueror of Space* (New York, Horace Liveright, 1930), p. 83.

job with the Western Electric Company in Chicago. His vicissitudes during the next two years are described vividly in his diary:*

August 12, 1899. Away to Chicago. . . . The third place I applied for a job, the Western Electric Company, . . . took me into their Dynamo Department. I work like a nigger from 7 a.m. to 5:15 p.m. Too much chasing of parts and mopping grease for me to learn much. $8 a week. . . .

October 15, promoted to the telephone laboratory, goal of my hopes. . . .

There is one free private library here, the Crerar, cozy, with dark wood tables and shaded lamps, where the chairs just seem to fit. I take great comfort in reading there. I have begun a systematic search through Science Abstracts, Wiedemann's *Annalen*, etc., for some hint or suggestion of an idea for a new form of detector for wireless signals. I had built a Branly coherer at Yale and used it. Marconi's coherer, and tapping-back, did not appeal to me. It was too slow and complicated. . . .

November 5, 1899. Finally, in the April number (1899) of Wiedemann's *Annalen* in an article by Aschkinass, I found a brief description of a phenomenon newly discovered which promised to be the solution to my problem . . . which, in a previous page of my diary, I had stated to be: "What wireless telegraphy requires is a self-restoring detector, which would permit the operator to hear in the headphones the sound, as it were, of the transmitter spark. . . ."

Dean and Smythe, co-workers of mine in the Western Electric Laboratory, began to take casual interest in what I was doing, although neither knew much about wireless telegraphy or Hertzian waves, nor shared my enthusiastic belief as to the enormous developments in electrical science which awaited further perfection of the crude transmitting and receiving apparatus which was then in use in Europe. . . .

March 18, 1900. Experiments on my new wireless "Responder," as I then called it, began to occupy more and more of my time. My work on telephone tests and devices was never brilliant, to speak charitably, for my thoughts were ever elsewhere. Dean became progressively more impatient with my work, but was too considerate to fire me, although he saw little of merit or promise in the experiments I was wrapped up in. Certainly he saw no possibility that the great

* From an unpublished diary. By permission of the author.

Western Electric Company would ever become interested in Wireless Communication!

One day he exclaimed: "Look here, de Forest. You'll never make a telephone engineer. As far as I am concerned you can go to hell, in your own way. Do as you damn please!" With typical recklessness I took him at his word, turned to my little corner where I had my spark gap and responder parts, and thereafter spent eight hours a day at my own delectable tests, totally oblivious to the telephone work going on about me and for which I was supposed to be paid. . . .

Following the German idea, which was obviously impractical as a wireless detector, I sought to overcome the pernicious tendency of the Responder to stop responding after a few seconds or minutes of operation. . . .

Now it was that Ed Smythe proved himself to be a practical, modern, electrically-minded engineer. He was swift to grab the significance of my experiments, watched my work with interest, discussed the problems with me, and occasionally contributed helpful practical criticism and advice.

April 8, 1900. At last I have the opportunity to do experimental work in wireless telegraphy. This came as the result of my having written to Professor Johnson of Milwaukee, president of the newly organized American Wireless Telegraph Company. Not long after, he came to see me in Chicago and asked me to join his concern.

Milwaukee, May 1, 1900. Started on my wireless telegraphy work at 809 Grand Avenue. Professor Johnson and his assistant, Fournier, were working on an impractical system of wireless reception, employing a coherer with iron filings (of all possible materials!) . . .

Becoming disgusted with the Johnson-Fournier "non-receiving set," I brought out my Chicago responder and a telephone receiver, and within an hour was receiving signals from Johnson's "plop-plop" transmitter. Lyman, slyly watching over my shoulder, soon grasped the idea of what I was doing. . . .

The work continued for three months. Lyman then begged me to give my responder to the company and when I refused he told about it to Johnson and I was called up on the carpet before him. I told him that the responder was my invention and would be used in no company but my own. So I was fired and took the night boat back to Chicago.

August, 1900. Smythe and I applied for our first patent, directed to our various improvements which would distinguish our invention from the Aschkinass disclosure and claim as broadly as possible what

we considered would be practical and patentable. Of necessity Smythe became my financier. Notebook entries:

August 29.	Lent de Forest, patent application	$22.50
	Lent de Forest, personal	1.00

September 3, 1900. I am starting in a new job with poor pay. But I am on the right track and feel that it is destined to make me independent.

Nights I worked with partner Smythe in my room, on the Responder. Without much delay I got a job as assistant editor on the staff of the *Western Electrician.* Salary was $10 a week. Every night not spent in the library was devoted to experimenting with the electrolytic anti-coherer. Smythe was comparatively rich, earning $30 a week. Naturally, our budget for experimental work was very limited. . . .

October 28, 1900. I have begun to hazard my job with the *Western Electrician* by working half-time in the laboratory of Armour Institute, teaching two nights weekly at Lewis Institute. I am risking mediocricy and weak contentment for a chance of great success. . . .

Soon the experiments became so engrossing that it was impracticable for me to continue to work even half time for the *Western Electrician.* So once more I crossed the Rubicon, burned my bridges, and with only the amount of $5 paid by Lewis Institute per week, and an equal amount advanced by Smythe, determined to continue my life as an inventor. . . .

December 23, 1900. Smythe has been cautious, diffident, lacking confidence, as he well might. Time is short and Marconi sails fine and weather-worthy boats, and these boats already headed toward America. If our craft cannot meet him next spring it might as well sink now.

De Forest's first chance to demonstrate his wireless apparatus came in 1901 with an offer from the Publishers' Press Association, which was willing to pay him $800 if he could successfully report the International Yacht Races. The trial was a failure.

De Forest had been able to borrow $1,000 to manufacture his equipment for the races, and later that year, through the sale of stock to the public, he got an opportunity to set up a laboratory of his own. He proved a prolific inventor. Between 1902 and 1906, he took out 34 patents on all phases of wireless telegraphy,

including loop antennas, receiver tuning, generators and antenna de-icers.[28]

His major search, however, was for a detector which would not infringe the Marconi or Fessenden patents. In this he was unsuccessful. The responder, on which he pinned so much hope in his diary, never proved satisfactory. His next attempt, the Wollaston wire electrode, was adjudged to have infringed the Fessenden electrolytic detector; and a further effort, the Spade electrode, involved only such minor changes that it was attached for contempt of court by Fessenden's company. De Forest then decided to return to some earlier experiments he had made, in an effort to devise an entirely new form of detector.

In 1900, while working with Smythe on the responder, he had noticed that the gas light in the laboratory dimmed while his spark equipment was operating, and that it returned to full strength when the apparatus stopped. This suggested that a gas flame might be used to detect wireless signals (later the dimming of the flame was shown to have been caused by sound waves from the spark gap). De Forest, therefore, tried to make a detector consisting of a bulb filled with gas and containing two electrodes intended to be heated by a dynamo. This gas detector was later described by the courts as "utterly useless."[29]

However, it led to the invention that was to revolutionize the radio art.[30] Continuing to experiment with gas-filled and partially evacuated two-element tubes, de Forest placed a third electrode, called a grid (because it was shaped like a gridiron), between the incandescent electrode (the cathode) and the cold electrode (the anode). He then attached a battery; and, by changing the voltage on the grid, he was able to control the flow of current across the space between the hot and cold electrodes. By making the grid negative, all the electrons could be forced back into the cathode; by making the grid positive, the electrons could be drawn from

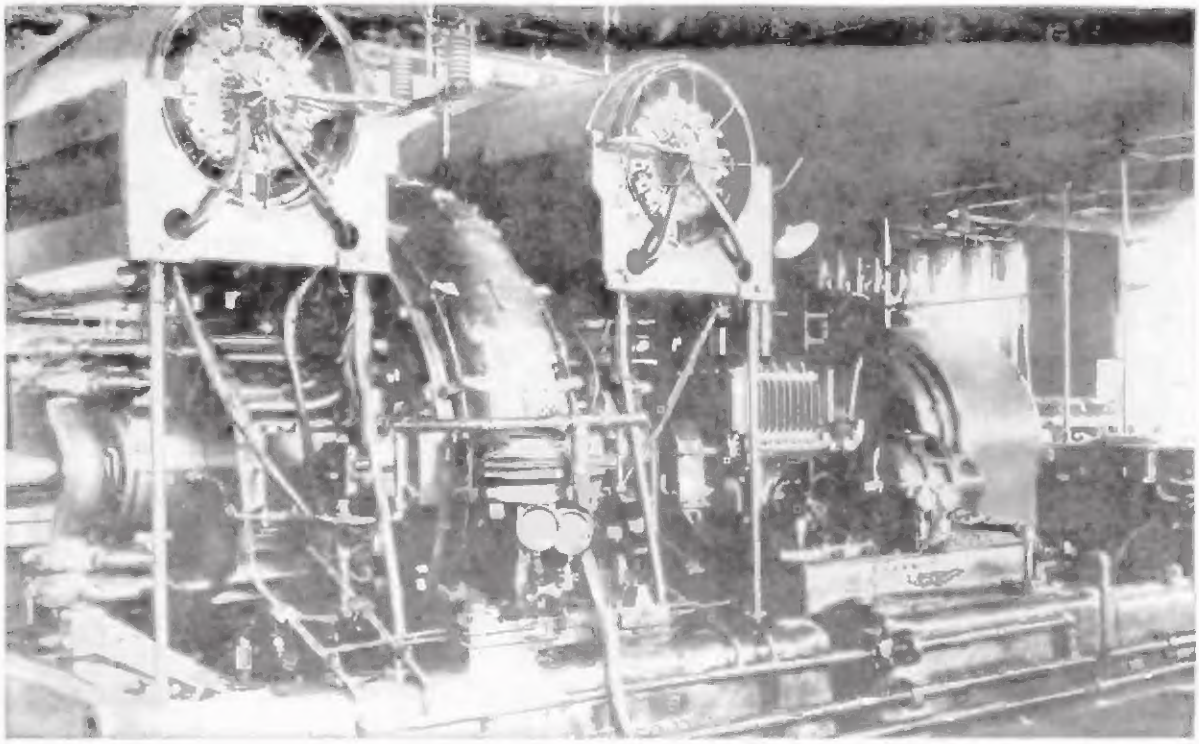
[28] Carneal, *op. cit.*, p. 165.

[29] Decision of the District Court, Marconi Wireless Telegraph Company of America *vs.* De Forest Radio Telephone and Telegraph Company, *op. cit.*, Sept. 20, 1916.

[30] U.S. Patent No. 879,532 was applied for January 29, 1907, and issued February 18, 1908. Lubell reports that it took de Forest three weeks to raise the $15 necessary for the patent application. Samuel Lubell, "Magnificent Failure," *Saturday Evening Post*, Jan. 24, 1942, p. 36.

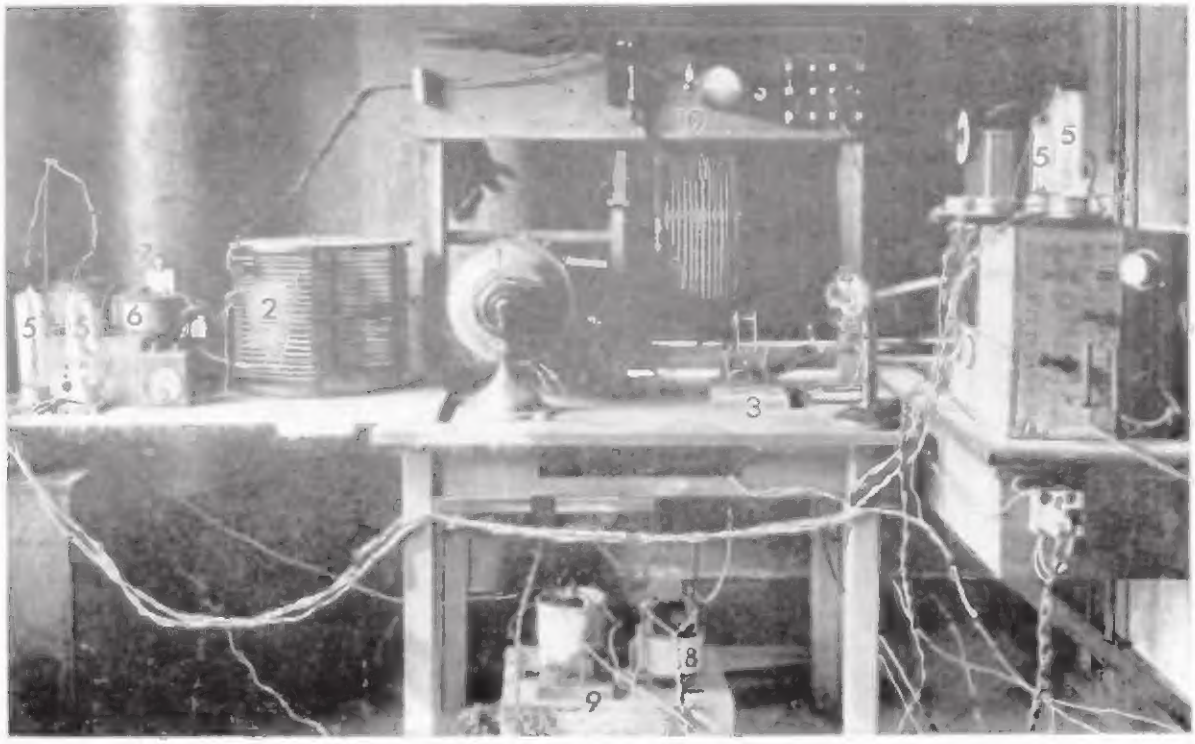
Transmitting equipment for the American Telephone & Telegraph Company's transatlantic radio telephone tests with the Eiffel Tower, 1915. The antenna towers at the Naval Station, Arlington, Virginia, were loaned for these experiments. Five hundred tubes were mounted on racks and connected in series to constitute the high-frequency amplifier. (Courtesy American Telephone & Telegraph Company)

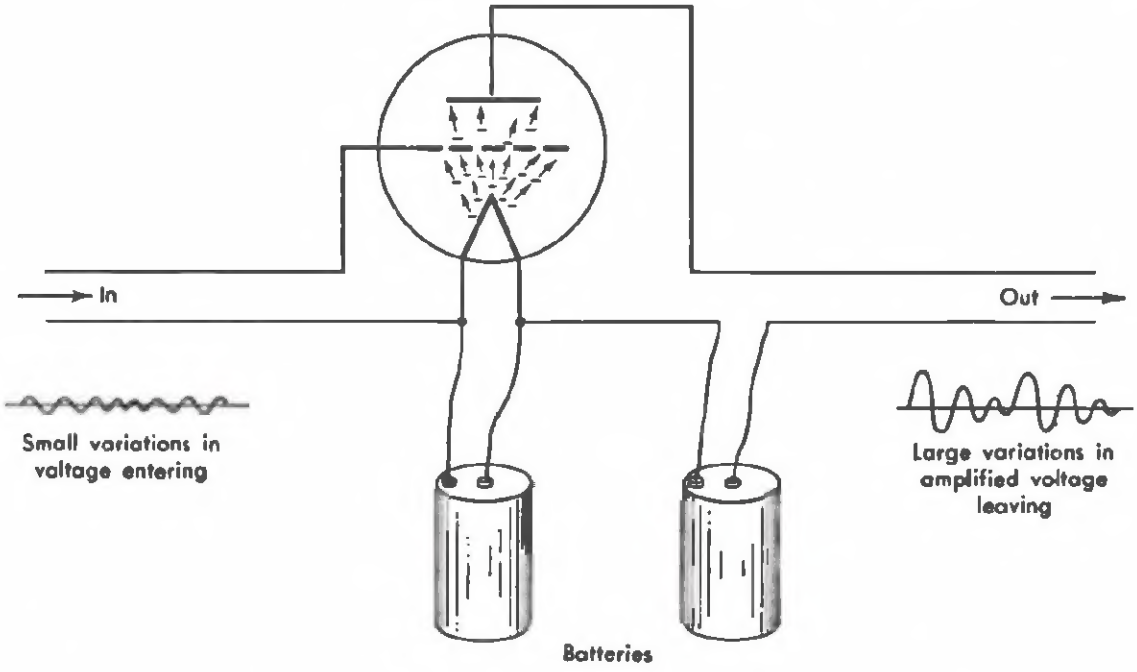
The New York control room of the Bell System overseas radio-telephone service, 1947. The technicians are making necessary adjustments to obtain maximum efficiency on these channels. (Courtesy American Telephone & Telegraph Company)



200 kw. Alexanderson high-frequency alternator installed in Naval Radio Station, New Brunswick, New Jersey, 1918. (Courtesy General Electric)

Equipment used by Dr. Frank Conrad for amateur broadcasting, prior to the establishment of KDKA. This was station 8XK. 1, Rotary spark gap; 2, Antenna tuning coil; 3, Antenna change-over switch; 4, Microphone; 5, Vacuum tubes; 6, Variable condenser; 7, Fixed condenser; 8, High voltage transformer; 9, Keying relay, and 10, Antenna ammeter. (Courtesy Westinghouse Electric Corporation)





Operation of a triode. With the addition of a grid, minute currents may be amplified considerably. (Courtesy Stokley, *Electrons in Action*, Whittlesey House)

the cathode as fast as they were emitted.[31] De Forest then connected the aerial of a receiver to the grid. The alternating current of the incoming electro-magnetic waves would successively affect the grid with positive and negative charges. When the negative half of the received wave reached the grid, the grid would repel the electrons being emitted from the hot cathode. At the same time the positive phase of the incoming signal would act on the grid to reinforce the positive charge of the cold electrode and thus help to draw electrons across the tube. This provided a much more effective method of control than could be obtained in the Fleming diode, where the emission of electrons was controlled by the degree of heat applied to the cathode.

De Forest himself did not fully understand the principles of the triode. Despite his doctoral training, he was much more an inventor than a scientist. According to some of his former associates, de Forest read intensively in the scientific literature, with the

[31] Eccles, *op. cit.*, p. 141. The principle of grid control had been used previously by the German physicist Lenard, for "studying the motion and nature of the electrons liberated from a zinc cathode by ultra-violet light," but Lenard had not conceived of its use for the detection or amplification of wireless signals.

object of discovering new principles which would enable him to invent devices rather than to understand or improve inventions he had already made. He did not attempt to relate his experiments to the general literature of physics, and consequently overlooked clues which might have assisted him in making a more useful electronic device. At first he believed that the presence of some residual gas was essential to the operation of his triode. A knowledge of Richardson's theory of thermionic emission might have suggested the possibilities of developing a detector with a pure electron discharge in a high vacuum—which was what Arnold and Langmuir later accomplished.

Another of de Forest's handicaps was his lack of adequate manufacturing facilities for producing tubes. In consequence, his triodes were not uniform in performance and proved less satisfactory than other competing devices, such as the electrolytic, magnetic and crystal detectors.[32]

Between 1907 and 1912 de Forest made few scientific experiments with the triode. He turned his attention primarily to wireless telephony, giving his first demonstration in the spring of 1907, between a Lackawanna Ferry and the Hoboken and Manhattan terminals. Within a short time, the Navy installed radio telephone sets on a number of ships; and, in the tests that followed, communication over twenty miles was achieved. But the company was inadequately financed, and the volume of radio sales was not large enough to sustain an effective program of development. When his laboratory was destroyed by fire in 1908, he took a year to re-equip it.[33] Finally, in 1911, the plight of the company became so desperate that de Forest went to Palo Alto to work for Federal Telegraph at a salary of $300 a month while waiting for some miracle to lift his firm from the economic doldrums.

De Forest worked in the Federal laboratories for nearly two years. For the first time he was relieved of commercial pressure and of the necessity of dividing his talents between inventing and

[32] While inherently superior to other detectors, de Forest's triodes needed such constant attention and such frequent adjustment of plate potential and filament current that commercial users found them too bothersome.

[33] All his records were destroyed in this fire. The loss of his notebooks proved a serious handicap during the lengthy vacuum-tube litigation that was to follow.

financing. He has described his tenure at Federal as among his "happiest and most useful years."[34] The research team of de Forest, Herbert Van Etten and Charles Logwood worked successfully on problems of high-speed telegraphy, static reduction and long-range transmission. One of de Forest's principal achievements during this period was the construction of transmitters and receivers, which would allow speeds of 90 words per minute between Los Angeles and San Francisco.

In 1912 de Forest undertook some new experiments with the triode. He connected first two, then three, audions in cascade; and, by feeding the output of the first tube into the input of the second, and the output of the second into the input of the third, he was able to obtain amplification far greater than that of a single tube. He used these cascades as telephone repeaters and described their effectiveness for the purpose in a letter to his friend John Stone Stone, a consulting engineer in New York. Stone, who knew of the Telephone company's search for such a repeater, brought the triode to the attention of Chief Engineer J. J. Carty; and de Forest was invited to demonstrate his device. The demonstration took place in October, 1912, and in the following spring the Telephone company purchased telephone repeater rights in the triode for $50,000.[35]

Back in Palo Alto, de Forest continued his investigations of the triode. He discovered that not only could the triode act as a detector and amplifier, but it could also be used as an oscillator to *generate* electro-magnetic waves.[36] This was a discovery that was to prove of great significance. The Marconi spark apparatus, the Poulsen arc and the Alexanderson alternator were all expensive and cumbersome. They have since been displaced by power tubes which had their origin in de Forest's work.

De Forest first put his new discovery to use for heterodyne reception of continuous-wave signals. The Fessenden heterodyne system used an arc to generate the high-frequency current which

[34] Carneal, *op. cit.*, p. 239.

[35] The research of the Telephone company on the triode will be discussed in Chapter V. AT&T subsequently paid $90,000 for the radio rights to the triode.

[36] The use of the triode as an oscillator was later to become involved in a four-party interference among Langmuir, Meissner, Armstrong and de Forest. De Forest eventually won the contest and was awarded the covering patents in 1924.

was combined with the incoming signal. De Forest, in competition, devised a compact, oscillating triode circuit, called the "ultraudion," for installation in Federal Telegraph stations The Navy became a large customer for these circuits.[37]

The Feedback Circuit

After the triode, the other principal invention with which de Forest's name is associated, is the feedback circuit, which could be used either to generate oscillations or to increase the sensitivity of the audion as a detector. Priority of invention here was claimed by both de Forest and Edwin Armstrong, and this dual claim produced the most controversial litigation in radio history. Armstrong, a graduate assistant at Columbia University, had delivered a paper before the Institute of Radio Engineers in 1913 in which he described a new "regenerative circuit." This circuit, he stated, made the triode a much more effective and sensitive detector of wireless signals. Five months later, de Forest applied for a patent on the same principle. Since the invention soon proved to be of great commercial importance, the question of whether de Forest or Armstrong had first made the discovery became crucial. De Forest produced notebooks to prove that, while working in his laboratory in Palo Alto, he and his associate, Van Etten, had observed that when they connected the output circuit back into the input circuit of the same tube, the amplification of the triode was increased. He was unable to show that he had made any use of this discovery, or had explained its operation technically. His opponents contended that, if he had understood it, his cascade amplifier, using several tubes, would have been superfluous.

Armstrong won the first round;[38] and in 1917 de Forest sold

[37] The Navy by this time had completely switched to continuous-wave apparatus. The "tikker" receivers developed by Federal Telegraph for use with Poulsen arcs were constantly getting out of order. And, while the Navy was anxious to use heterodyne reception, the small arcs supplied by the Fessenden company were subject to frequent breakdowns. The ultraudion circuit was thus a lifesaver to the Navy.

[38] The Supreme Court in 1928 reversed the decisions of the lower courts and awarded priority to de Forest. Six years later, when the issue again reached this court, a similar decision was rendered. However, the Franklin Institute, in its report awarding the Franklin Medal to Armstrong in 1941, said that this decision was made "much to the astonishment of radio engineers . . . It is generally con-

the feedback patents, all his remaining radio telephone patents and all vacuum-tube inventions that he might make in the next seven years to the Telephone company for $250,000.[39] This point marked the decline of de Forest's interest in radio. He turned his attention to talking movies, reviving his earlier interest in sound-on-film,[40] and from that time on made no further contributions to the radio art.

De Forest as an inventor lacked the persistence to carry any one project through to a completely successful conclusion. Like many highly creative individuals, he had far more ideas than he was capable of handling. And his restless mind was always seeking new fields to explore, demonstrating what Taussig has described as "the irresistible urge to invent."[41]

He would sweep down on a problem with a hungry rush and his imagination had an astonishing faculty for leaping difficulties. If the quarry snagged or proved elusive, however, he had to hop to something else. When necessity did compel him to work at something without respite, his nerves rebelled. "The jumpies" de Forest called these attacks.[42]

(b) THE INNOVATOR

De Forest, like his American rival, Fessenden, had little of the entrepreneurial ability displayed by Marconi. De Forest's high inventive skill enabled him to launch a large number of com-

ceded by the radio engineering fraternity that de Forest was endeavoring to suppress the unwanted oscillations which occurred in his apparatus, while Armstrong, understanding the nature of the phenomena, was working to control and make use of these continuous oscillations. This view was reflected in the presentation to Armstrong in 1918 of the first Medal of Honor awarded by the Institute of Radio Engineers. When the final decision of the Supreme Court was handed down, Armstrong, in 1934, returned the Medal to the Institute. The Institute thereupon gave it back to him, re-affirming the award and indicating their conviction of his priority of invention." The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, Committee on Science and the Arts, Report No. 3087, Jan. 8, 1941, pp. 3–4.

[39] Archer, *History of Radio*, *op. cit.*, p. 135. De Forest's share amounted to about $175,000. Lubell, *op. cit.*, Jan. 31, 1942, p. 40.

[40] His phonofilm was patented in 1904.

[41] See Taussig, *op. cit.*, pp. 23–24. "The instinct of contrivance in man unlike the corresponding instinct in animals, is not directed to one specific end. . . . It is directed to all sorts of contrivances no longer restricted to those immediately serviceable. . . . There seems to develop an erratic streak."

[42] Lubell, *op. cit.*, p. 41.

panies, but none of these survived long. He seemed incapable of building on solid foundations an enterprise in which stable customer relations were cultivated. The first of his promotional ventures was the De Forest Wireless Telegraph Company, started in 1901 with an investment of $1,000 obtained from a business acquaintance.[43] De Forest rented a small machine shop in Jersey City to make equipment for reporting the international yacht races. When this proved a failure, he set out for Wall Street in quest of additional funds. Reputable capitalists were not interested. After countless rebuffs, he found an over-the-counter broker who helped him to raise a few hundred dollars.[44] With this amount he built a trial transmitting station in Jersey City.[45] Then in the fall of 1901, de Forest met a stock promoter, Abraham White, who became very much interested in the financial possibilities of a radio company.

At White's suggestion the American de Forest Wireless Telegraph Company was incorporated, with an authorized capital of $3,000,000.[46] This new venture had some initial success.[47] In 1902 de Forest received an order from the War Department to install his receiving apparatus on one of the Army tugboats and to erect two land stations for the Signal Corps.[48] When these were completed and tested, he was asked to build two land installations for the Navy. Hitherto the Navy had purchased most of its wireless apparatus from the German Slaby-Arco corporation.[49] In 1904 de Forest's company built a radio link for the United Fruit Company between Costa Rica and Panama.[50] In 1905 the Navy awarded the De Forest company its largest con-

[43] Carneal, *op. cit.*, p. 125.

[44] *Ibid.*, p. 141.

[45] This was the first transmitter to use alternating current as a source of supply.

[46] During this period the de Forest system was demonstrated to George Westinghouse, who professed not to be interested in this new development. Carneal, *op. cit.*, p. 147.

[47] *Electrical World*, March 8, 1902, p. 458.

[48] Carneal, *op. cit.*, p. 148.

[49] This later became Telefunken (see Chap. III). *Ibid.*, p. 149.

[50] The Fruit company was to become an important purchaser of radio apparatus. The company's early interest in wireless stemmed from the need for rapid communication between ports and ships carrying a perishable commodity. Much of de Forest's early work on improving ground connections and eliminating static resulted from the special difficulties of wireless working in the tropics, which he encountered at United Fruit stations.

tract to date—an order to construct five transmitting and receiving stations along the Gulf of Mexico.[51]

It was in 1906 that de Forest invented the three-electrode vacuum tube. This historic invention was not used at all by his original company, which was soon to experience serious financial difficulties. White, as promoter and president of the company, had grandiose ideas for expansion which de Forest apparently shared. They planned to erect a network of wireless land stations to rival Western Union and Postal. As described by Lubell:

> Off the printing presses poured prospectuses predicting that telegraph rates would be slashed to less than a cent a word and cable costs from twenty-five to two and a half cents a word. Wireless towers mushroomed over the United States, while glib salesmen told how "$100 invested in Bell Telephone stock rolled into $2,000,000" and promised that de Forest stocks will do the same.[52]

Over ninety stations were erected by the company, and more were projected. Many never sent a message.[53] Static interference proved so bad that reliable communication was impossible. White hoped to stave off bankruptcy by various devices. Typical was his newspaper announcement of 1906 that he had obtained control of American Marconi and planned to amalgamate these two companies. White succeeded in selling a substantial amount of stock before American Marconi was able to deny the rumor. In the late summer of 1907 two Denver speculators in the de Forest enterprises—Christopher Columbus Wilson and W. A. Debold[54]—interceded on behalf of the De Forest shareholders (they themselves having large De Forest holdings), put the company out of business and sold its assets to the United Wireless Telegraph Company which they organized. De Forest was forced to resign. He took with him, however, the patents pending to the triode, which nobody regarded as of much significance.

De Forest then joined with one of White's star stock salesmen, James Dunlop Smith, and together with his patent attorney, Samuel Darby, they formed a new corporation in 1907—the De

[51] *Electrical World*, March 31, 1906, p. 655.
[52] Lubell, *op. cit.*, Jan. 24, 1942, p. 35.
[53] *Ibid.*
[54] These two men and some of their associates were later sent to jail for stock frauds.

Forest Radio Telephone Company[55]—with a capitalization of $2,000,000.[56]

This concern set out to develop wireless communication by means of the radio telephone, a field which Fessenden had also been exploring. The Navy was the first customer and ordered twenty-seven sets to be used on fleet maneuvers in the Pacific.[57] The sets were hastily made; and, with no time to train operators before the fleet sailed round the world during the winter of 1907–1908, the results were disappointing, though not a complete failure. De Forest arc transmitters were employed in these sets and both crystal and vacuum-tube receivers. One wireless operator, Meneratti, developed the practice of broadcasting daily to the fleet, using phonograph records.[58]

In the meantime, de Forest's funds began to run low again; and he tried desperately to raise some more money by sales of stock. The methods that were followed have been described by an employee of this period:

> In 1908, I was night operator at the Atlantic City station of the American De Forest Wireless Telegraph Company on Young's Million Dollar Pier. This station had been designed largely for advertising. It was a glass house about the middle of the pier, and in the evenings I worked surrounded by a crowd of resort visitors, attracted by the noise of the spark.
>
> When I went on watch one evening late in August, I was told by Bob Miller, the day man, that a broker from Philadelphia would be in later on with a customer, and presently he appeared with a prosperous looking old lady. I showed them how things worked and let her listen to some signals from a ship, and then he started explaining what a wonderful opportunity to get rich he was offering.
>
> I listened in amazement and silence for about fifteen minutes, but finally he told her that the average amount collected monthly on each ship for messages sent was $500. Unfortunately, he turned to me. "You have been out on several ships, haven't you?"—"Yes."—"Didn't you take in about five hundred a month?"—"No, I never took as much

[55] Carneal, *op. cit.*, p. 198. This concern was aided by the acquisition of the assets and the especially important tuned-circuit patents of John Stone Stone. Since the De Forest company had insufficient funds for development, a subsidiary, the Radio Telephone Company, was formed.

[56] De Forest owned 50 per cent of the stock of this company.

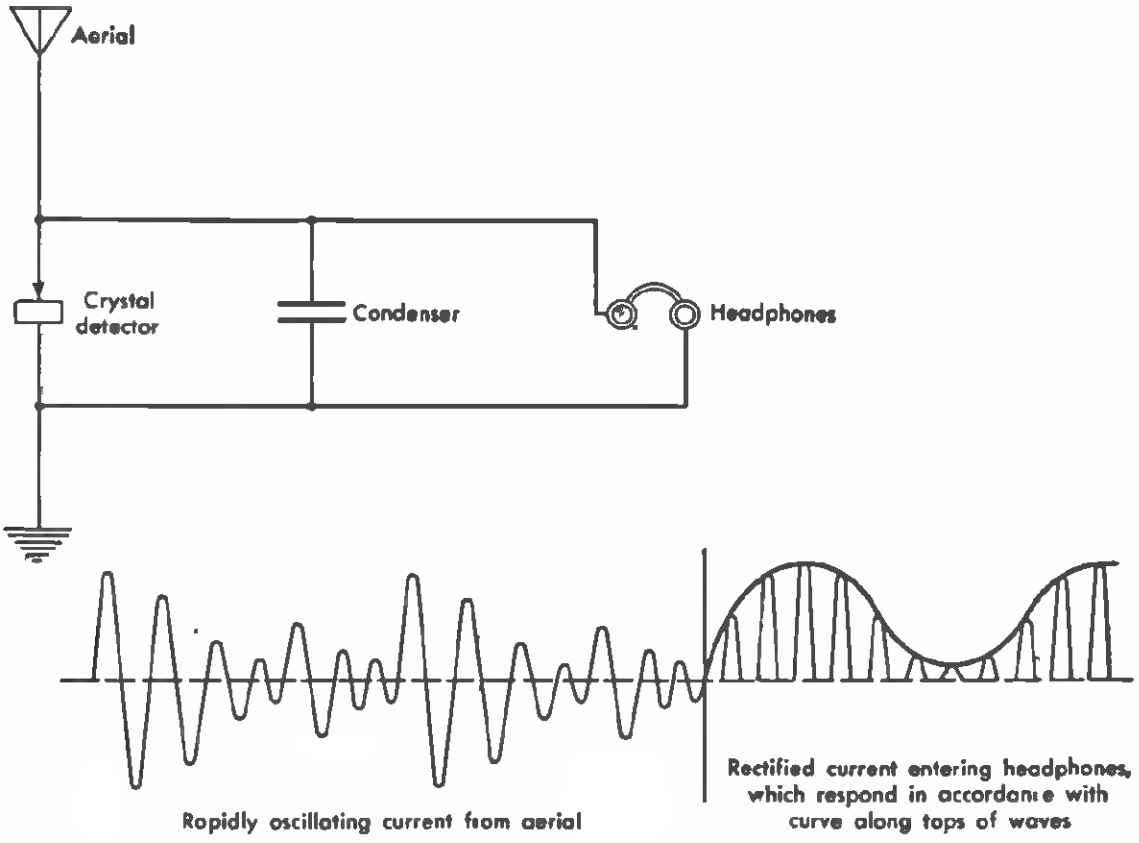
[57] Lubell, *op. cit.*, p. 38.

[58] Interview with George Clark, August, 1946.

as $50, and ten dollars would be about the average!"—He sputtered and stuttered, and finally took his prospect away.

Next morning at 9:00 a.m. I received a telegram ordering me to come to New York and sail for England on the *Tagus* at 3:00 p.m. I was tired of working 12 hours every day and Sunday for $80 a month anyway.[59]

In another type of salesmanship stunt, de Forest journeyed to France and obtained permission to use the Eiffel Tower. From there he broadcast in the summer of 1908, some of his messages being received as far as Marseilles. While in Europe, de Forest also demonstrated his apparatus to the British Admiralty, achieving transmission over sixty miles. Several sets were ordered by the Admiralty, but the Marconi company insisted on a literal interpretation of its exclusive contract, thereby forcing a cancella-



Operation of a crystal detector. The crystal rectifies the oscillations of current from the antenna, giving an output similar to that of a diode. (Courtesy Stokley, *Electrons in Action*, Whittlesey House)

[59] Witnessed statement of Austin M. Curtis from the files of Lloyd Espenschied.

tion of the order.[60] The following year de Forest planned communication between New York and Paris, but a severe sleet storm destroyed his wires and antennas.

Although sales of de Forest apparatus remained limited, with the Navy as the best customer, the company did become moderately successful for a short period. The high-power stations constructed for the Navy were excellent. De Forest knew how to get power into his equipment; his transmitters were characterized by a "good carrying spark"; and he was one of the few to realize the importance of good ground connections. By 1909 de Forest, with a new laboratory and seven assistants, declared: "Never until this year have I had the proper backing."[61] Had he been content to improve and perfect his apparatus progressively, he would have had a greater measure of commercial success. Instead, he was too ambitious and too impatient.

Always a showman, de Forest in January, 1910, staged the first opera broadcast in history, with Caruso singing in *Cavalleria Rusticana* and *Il Pagliacci.* The voices were hardly recognizable. More serious disappointments were to follow. The government was beginning a crusade against wireless stock promoters, and the plans to obtain more funds by stock and bond sales had to be abandoned. The Radio Telephone Company went into bankruptcy in 1911, following an unsuccessful merger into a $10,000,000 North American Wireless Corporation;[62] and de Forest went to California to work for Federal Telegraph.

In May, 1912, de Forest and his associates were charged with using the mails to defraud. During the course of the trial, the government prosecutor showed how little understanding there was of the significance of de Forest's inventions when he accused the defendants of selling stock "in a company incorporated for $2,000,000, whose only assets were de Forest's patents chiefly directed to a strange device like an incandescent lamp which he called an Audion and which device had proven worthless."[63] But the government proved conclusively that unscrupulous methods

[60] Carneal, *op. cit.*, p. 226.

[61] From a speech by de Forest, as reported in the *New York Times*, Feb. 14, 1909.

[62] According to Lubell, de Forest was given $1,000,000 stock and $250,000 cash in this company. Lubell, *op. cit.*, Jan. 24, p. 38.

[63] Archer, *History of Radio*, *op. cit.*, p. 110.

had been employed in promoting the Radio Telephone company. De Forest himself was exonerated on the grounds that he had not been responsible for the unlawful practices used, though two of his associates were sent to jail.

Undaunted, de Forest used the $50,000 obtained from the sale of repeater rights in the triode to reorganize his old company, changing its name to The Radio Telephone and Telegraph Company.[64]

The following year, 1914, de Forest sold further triode rights for radio, to AT&T, and with the $90,000 began to manufacture triodes under the limited rights he had retained for "amateur and experimental use." The company centered its efforts on the production of tubes for oscillating circuits, which would give high-frequency output in useful quantities for heterodyning. New equipment was installed in de Forest's laboratory and modern machinery and pumps purchased for the factory. By then the triode had become easier to use and less expensive because better and cheaper batteries and charging equipment had been placed on the market.

In the meantime, the Marconi company brought a patent suit, claiming that the triode infringed the Fleming valve. De Forest immediately filed countersuit, averring that the Marconi company had infringed his patent by its use of the third element. In September, 1916, the court decided that de Forest had infringed the two-element Fleming valve, while Marconi had infringed the three-element de Forest patent.[65] Neither company could manufacture the triode.

During the war, however, de Forest manufactured triodes under government immunity;[66] but at the conclusion of hostilities some sort of working compromise with the Marconi company was essential. For a brief period the two companies tried to work together. A lamp manufacturer named Moorehead assem-

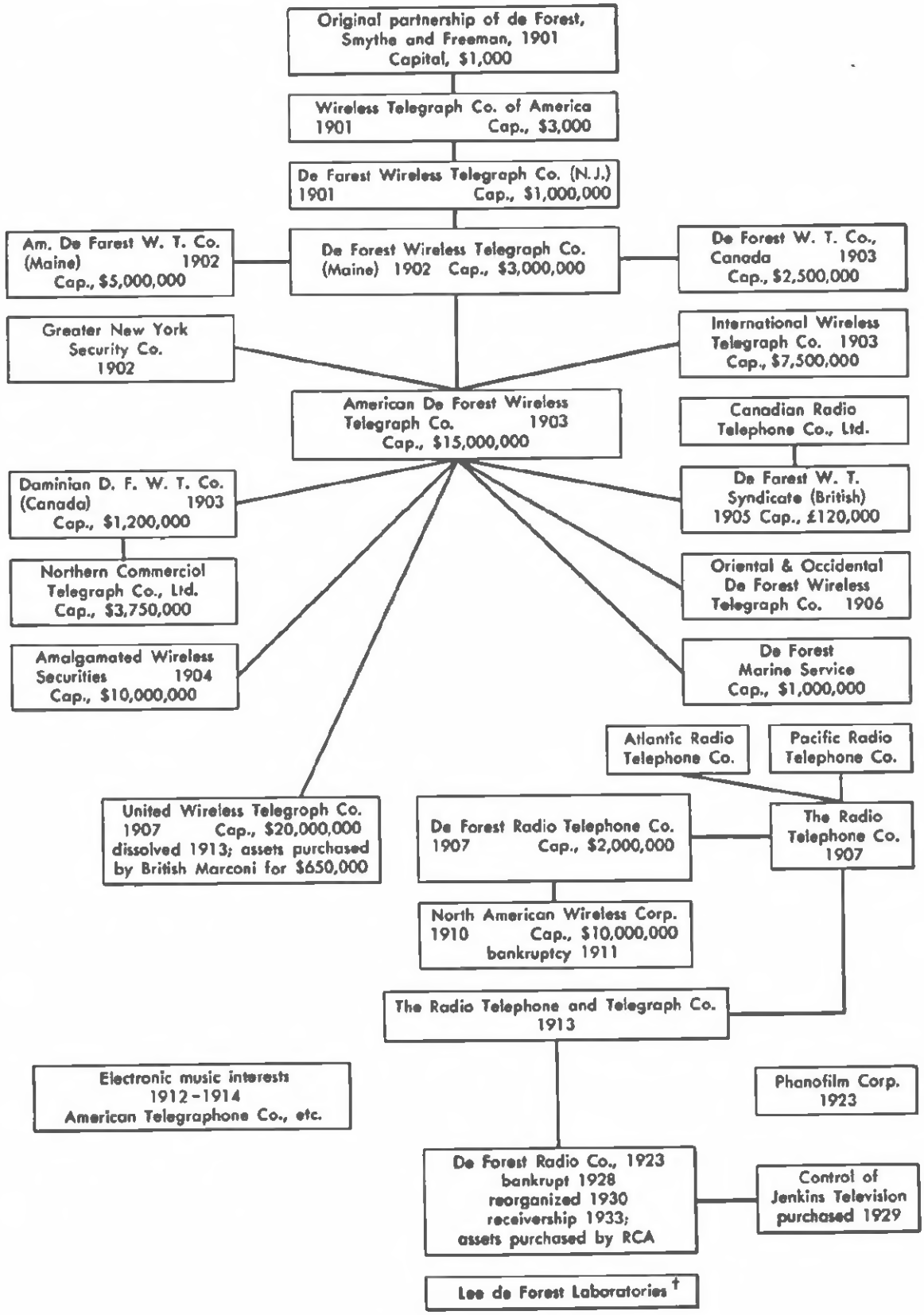
[64] De Forest owned about 80 per cent of the stock of this company.

[65] The Marconi company had first used three-element tubes at the United Fruit Company's station in New Orleans in order to fulfil a $100,000 contract which was in jeopardy due to unsatisfactory performance of magnetic and carborundum detectors. 236 F. 942, affirmed 243 F. 560.

[66] His triodes were not uniform or standardized, and the entry of such firms as Western Electric and General Electric into tube manufacturing pointed up the deficiencies of the de Forest product.

TABLE III

THE DE FOREST COMPANIES *



bled triodes for de Forest, who passed them on to the Marconi company for exclusive distribution in the United States. The first order for 150,000 tubes brought in substantial revenue. But quarrels soon developed. And when in 1920 RCA acquired rights to the triode through cross-licensing agreements with the Telephone company, it was no longer necessary to deal with de Forest. In the competitive struggle that ensued, de Forest's company was no match for GE, Westinghouse and RCA.

Thus, although de Forest was perhaps the most imaginative inventor in the history of the radio industry, and had the opportunity to create a great radio enterprise, he failed entirely to do so. His career, when compared with Marconi's, effectively illustrates that an inventor, to achieve commercial success, must associate himself with men of exceptional business judgment.

* This is not a complete table of de Forest's companies but only those on which we have been able to find a record. De Forest himself did not remain associated with all the companies that bore his name. Almost all the de Forest companies were capitalized for much more than the company ever received in cash or tangible assets. Indicative of de Forest's attitude toward financial matters is an entry in his diary, made during his student days: "I always seem lost in the financial woods."

† This is de Forest's present venture. The Laboratories are located in Hollywood and produce principally diathermy machines.